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Various modifications of a vascularized nasoseptal flap for repair of extensive skull base dural defects

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OBJECTIVE Endonasal surgery of the skull base requires watertight reconstruction of the skull base that can seal the dural defect to prevent postoperative CSF rhinorrhea and consequent intracranial complications. Although the incidence of CSF leakage has decreased significantly since the introduction in 2006 of the vascularized nasoseptal flap (the Hadad-Bassagasteguy flap), reconstruction of extensive skull base dural defects remains challenging. The authors describe a new, modified vascularized nasoseptal flap for reconstruction of extensive skull base dural defects.

METHODS A retrospective review was conducted on 39 cases from 2010 to 2017 that involved reconstruction of the skull base with an endonasal vascularized flap. Extended nasoseptal flaps were generated by adding the nasal floor and inferior meatus mucosa, inferior turbinate mucosa, or entire lateral nasal wall mucosa. The authors specifically highlight the surgical techniques for flap design and harvesting of these various modifications of the vascularized nasoseptal flap.

RESULTS Thirty-nine endonasal vascularized flaps were used to reconstruct skull base defects in 37 patients with nonsurgical or postoperative CSF rhinorrhea. Of the 39 procedures, extended nasoseptal flaps were used in 5 cases (13%). These included 2 extended nasoseptal flaps including the inferior turbinate mucosa and 3 extended nasoseptal flaps including the entire lateral nasal wall mucosa. These 5 extended nasoseptal flaps were used in patients who had nonsurgical CSF rhinorrhea due to extensive skull base destruction by invasive pituitary tumors. All flaps healed completely and sealed off the CSF leaks. Olfactory function slightly decreased in the 3 patients with extended nasoseptal flaps including the entire lateral nasal wall mucosa. One patient experienced nasolacrimal duct obstruction, which was treated by dacryocystorhinostomy. The authors encountered no wound complication in this series, while crusting at the donor site required daily nasal toilette and frequent debridement until the completion of mucosalization, which usually takes 8 to 12 weeks after surgery.

CONCLUSIONS Extended nasoseptal flaps are a reliable and versatile option that can be used to reconstruct extensive skull base dural defects resulting from destruction by large invasive tumors or complex endoscopic endonasal surgery. An extended nasoseptal flap that includes the entire lateral nasal wall mucosa (360° flap) is the largest endonasal vascularized flap reported to date and may be an alternative for the reconstruction of extensive skull base defects while avoiding the need for additional external approaches.

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KEYWORDS cerebrospinal fluid rhinorrhea; endonasal vascularized flap; endoscopic endonasal approach; extended nasoseptal flap; skull base reconstruction; vascularized nasoseptal flap

Endonasal skull base surgery requires watertight closure of the skull base dura to seal the dural defect and separate the intracranial space from the sinonasal cavity, thus preventing postoperative CSF rhinorrhea and consequent intracranial complications. Since both microscopic and endoscopic endonasal approaches are increasingly used for the management of sellar, parasellar, and ventral skull base lesions,[9,24,37–39] the techniques for skull base reconstruction following endonasal skull base surgery have advanced.[1,4,7,10,19,21–23,26,36] In 2006, the use of a vascular pedicled flap from the nasal septum mucoperiosteum and mucoperichondrium based on the nasoseptal ar-

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tery (Hadad-Bassagasteguy flap) was introduced,[15] which has significantly decreased the incidence of CSF leakage in the postoperative period after endonasal skull base surgery.[17,18,20,40] This technique yields superior outcomes to free tissue grafts, because vascularized flaps promote faster and more complete healing by restoring the local blood.[15,25,32]

However, a vascularized nasoseptal flap may not always be available for skull base reconstruction; its availability may be precluded if 1) the septum is damaged by prior surgery or disease involvement, 2) the blood supply is compromised during surgery, or 3) prior reconstruction using a nasoseptal flap has failed because of flap necrosis.[5] In these situations, the surgeon should be able to modify the design of vascularized nasoseptal flaps for skull base reconstruction depending on the location, size, and shape of the skull base defect. Although a conventional vascularized nasoseptal flap is sufficient in most cases, a larger vascularized flap such as an extended nasoseptal flap may be needed to provide complete watertight skull base dural closure in patients with CSF rhinorrhea resulting from extensive skull base destruction involving large invasive tumors.[31,41,42]

In the present study, we describe our experience repairing CSF leakage using various modifications of a vascularized nasoseptal flap. We also introduce a new type of extended nasoseptal flap, the so-called 360° flap, which can cover an extensive defect in the skull base.

Methods

We retrospectively reviewed 39 cases of reconstruction of a skull base defect with various types of endonasal vascularized flap for repair of CSF leaks in 37 patients between March 2010 and September 2017. All endonasal vascularized flaps were applied to patients with CSF rhinorrhea and were not used as preparation for routine transsphenoidal surgery. The study recorded the participants' demographic information, pathology, perioperative CSF leaks, skull base defect size and location, type of vascularized flap used, surgical data, and postoperative complications. All the reconstructions were performed by the senior neurosurgeon (S.H.K.) at Severance Hospital, Yonsei University College of Medicine, Seoul, Korea. All patients were followed up regularly after reconstruction and monitored with imaging and endoscopic examinations. A retrospective chart review of consecutive patients was approved by the institutional review board of our institution.

Surgical Procedures for an Extended Nasoseptal Flap Including the Inferior Turbinate Mucosa

The easy way to obtain a flap wider than the conventional vascularized nasoseptal flap (type A, Fig. 1A) is to add the mucoperiosteum of the nasal floor and inferior meatus (type B, Fig. 1B). To extend the size of the flap to allow coverage of extensive skull base defects, modification of the flap by adding the mucoperiosteum of the inferior turbinate (i.e., an extended nasoseptal flap including the inferior turbinate mucosa) may be feasible (type C, Fig. 1C). After decongestion of the nasal cavity with topical application of cottonoids soaked in epinephrine (1/100,000), the nasal septum was infiltrated with normal saline into the subperichondrial layer for hydrodissection of the surgical plane between the nasal septum and the mucoperichondrium. Under visualization with a 0° endoscope, endonasal mucosal incisions were made using monopolar electrocautery with an angled Colorado needle tip (Stryker) on a low current. The incision was initiated at the apex of the posterior choana at the lowest level of the sphenoid floor and extended laterally and crossed the nasal floor over the junction of the soft and hard palates from the nasoseptal side of the choana to the most posterior aspect of the inferior meatus (Fig. 1C 1→2→3). The posterior incision was turned 90° from the nasal floor, superiorly passing over the tail of the inferior turbinate, which is 1 cm anterior to the most posterior part of the inferior turbinate, and progressing anteriorly just above the inferior turbinate in the middle meatus following the sagittal plane (Fig. 1C 3→4). Then, a vertical anterior incision was made in front of the head of the inferior turbinate and continued over the floor of the nasal cavity to the nasal septum (Fig. 1C 4→5). The nasolacrimal duct opening was spared by curving the incision to pass the posterior edge of the opening. Then, the superior incision was made following the sagittal plane of the septum from the upper part of the sphenoid ostium located 1 cm below the most superior aspect of the septum (preserving the olfactory epithelium) (Fig. 1C 6→7). The anterior and superior incisions joined the vertical hemitransfixion incision at the septum (Fig. 1C 5→7). A narrow vascular pedicle consisting of a mucosal flap that contained the posterior nasoseptal artery confined between the incision just above the choana and the inferior border of sphenoid ostium was preserved.[15] The bony structure of the inferior turbinate was left in place for reepithelialization, thus reducing the morbidity of this procedure.

Surgical Technique for a 360° Flap

For patients with an extremely large skull base defect involving the entire anterior skull base, confirmed by 3D CT scanning and MRI, in which the precise CSF leakage point cannot be detected preoperatively, we developed an extended nasoseptal flap including the entire lateral nasal wall mucosa, the so-called 360° flap (type D, Fig. 1D). The incision for the lower part of the flap was performed in the same way as described for the extended nasoseptal flap including the inferior turbinate mucosa (Fig. 1D 1→6). Then, the incision on the septum continued superolaterally along the roof of the nasal cavity to the anterior aspect of the lateral wall of the nasal cavity (Fig. 1D 6→7) and joined the vertical incision (Fig. 1D 7→8) made along the anterior aspect of the head of the middle turbinate. Elevation of the mucoperiosteum from the bony component of the middle turbinate began at the vertical incision in the head of the middle turbinate and proceeded on either side of the middle turbinate in an anterior-to-posterior direction. This was followed by careful and meticulous removal of the middle turbinate bone in a piecemeal manner. Subperiosteal elevation of the mucoperiosteum covering the superior turbinate was subsequently carried out bilaterally along the medial and lateral slopes of the turbinate. After mucoperiosteum elevation, the bone of the superior turbinate was removed carefully in a piecemeal fashion in a similar manner. During the removal of the bony compo-

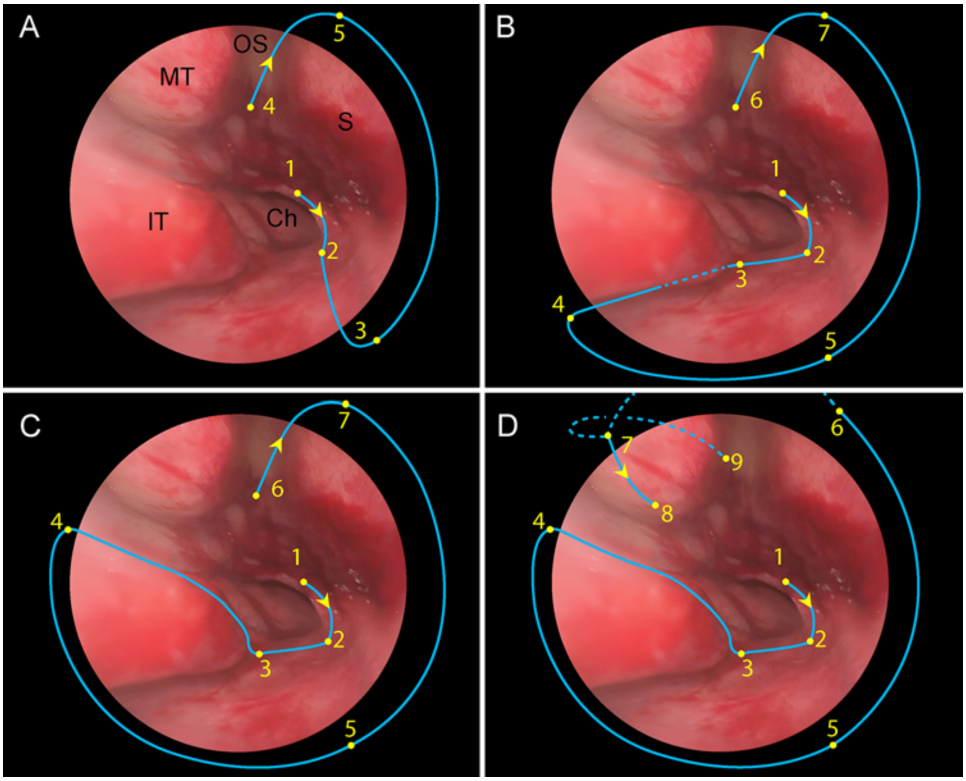

FIG. 1. Endoscopic view of the right nasal cavity and drawing of the incisions for various modifications of the nasoseptal flap. **A:** Type A. Conventional nasoseptal flap. **B:** Type B. Extended nasoseptal flap including nasal floor and inferior meatus mucosa. **C:** Type C. Extended nasoseptal flap including inferior turbinate mucosa. **D:** Type D. Extended nasoseptal flap including entire lateral nasal wall mucosa, the so-called 360° flap. Ch = choana; IT = inferior turbinate; MT = middle turbinate; OS = ostium; S = septum. Figure is available in color online only.

nents of the middle and superior turbinates, the vertical attachment of the turbinates to the skull base should be sharply transected to avoid inadvertent skull base fracture and CSF leakage. After removal of the bone, the lateral attachment of the mucoperiosteum was cut through the axilla of the middle turbinate until it reached the sphenoid ostium (Fig. 1D 7→9) and was detached from the lateral wall of the nasal cavity along the sagittal plane of the skull base. Then, the mucoperiosteum was unfolded in an open-book fashion, and elevation of the flap proceeded posteriorly as the basal lamella was transected. Next, the mucoperiosteum covering the inferior turbinate, nasal floor, and nasal septum was elevated from anterior to posterior in the subperichondrial and subperiosteal planes using a Cottle elevator. Elevation of the flap from the anterior face of the sphenoid sinus was achieved with preservation of the vascular pedicle. The mucosa of the nasal roof was cautiously elevated in the subperiosteal plane, and the elevation proceeded laterally to detach the mucoperiosteum from the superolateral wall of the nasal cavity. Finally, elevation of the 360° flap including the mucoperiosteum and mucoperichondrium of the nasal septum, nasal floor, inferior turbinate, nasal roof, superior turbinate, and middle turbinate was completed, preserving its posterior pedicle that contained the septal branch of the sphenopalatine artery (Videos 1 and 2).

VIDEO 1. Video clip of cadaveric demonstration of extended nasoseptal flap (360° flap). Copyright Sun Ho Kim. Published with permission. Click here to view.

VIDEO 2. Video clip of clinical case 5 using extended nasoseptal flap (360° flap). Copyright Sun Ho Kim. Published with permission. Click here to view.

It is helpful to complete all mucosal incisions before flap elevation because it becomes technically challenging to maintain tissue tension and to access the posterior nasal cavity once it has been elevated. Once harvested, the flap can be safely placed into the nasopharynx until the preparation of the surface around the skull base defect for flap attachment is concluded. The dural defects were covered with collagen fleece coated with fibrin sealant (TachoSil, Nycomed) patches. It is imperative that the flap is in direct contact with the margins of the defect and that all the mucosa along the skull base defect, the foreign body, and the nonvascularized tissue that remains between the flap and the surrounding edges of the defect are removed before application of the flap. After meticulous preparation of the surface around the skull defect, the flap was gently rotated and mobilized to cover the defect. Once the flap was positioned correctly and completely covered the defect, Bemsheets surgical pads (Kawamoto Bandage Material Co., Ltd.) soaked in antibiotic ointment were packed over the entire surface of the flap overlapping the edges, to hold the flap in place and to obliterate the dead space between the flap and the underlying tissue, ensuring that all aspects of the flap including the pedicle were in direct contact with the wider outer boundary of the bony defect. A polyvinyl alcohol sponge (Merocel, Medtronic Xomed) covered with the finger portion of a surgical glove was inserted to exert indirect compression of the flap against the defect. Care must be taken under endoscopic visualization when placing the packing to avoid compression of intracranial neural and vascular structures, dislocation of the flap, or compromise of the vascular pedicle. This nasal tampon may stay in place for 5 to 7 days. Silastic splints were placed over the exposed septal cartilage for approximately 2 weeks to protect the denuded septum and the lateral nasal wall during wound healing.

Results

Between March 2010 and September 2017, 1177 patients with pituitary adenoma underwent endonasal transsphenoidal surgery. During this period, 39 endonasal vascularized nasoseptal flaps were used in 37 patients for repair of CSF rhinorrhea. There were 9 men and 28 women who ranged in age from 15 to 71 years (mean 45 years). Of 39 flaps for endonasal reconstruction of a skull base defect, 29 were conventional vascularized nasoseptal flaps, while 10 were endonasal vascularized flaps other than conventional vascularized nasoseptal flaps (25.6%). These flaps included 5 middle turbinate flaps and 5 extended nasoseptal flaps (2 type C and 3 type D). All conventional vascularized nasoseptal flaps were used for repair of postoperative CSF rhinorrhea following transsphenoidal pituitary tumor surgery. Of the 5 middle turbinate flaps, 4 were used for repair of postoperative CSF rhinorrhea following pituitary tumor surgery and 1 was used to cover an exposed internal carotid artery.

Extended nasoseptal flaps were used for 5 patients who had large, invasive pituitary adenomas that had destroyed the skull base extensively. All 5 cases presented with nonsurgical CSF rhinorrhea before surgery. Three patients had medication-induced CSF rhinorrhea, which occurred after cabergoline medication for prolactinoma in 2 patients and pasireotide medication for Cushing's disease in 1 patient. One patient had CSF rhinorrhea 5 years after radiation therapy, and another patient had CSF rhinorrhea after partial removal of a pituitary adenoma via a transcranial approach. Depending on the size, shape, and location of the skull base defect, 2 patients underwent skull base reconstruction using an extended nasoseptal flap including the inferior turbinate mucosa (type C), and 3 patients underwent reconstruction using an extended nasoseptal flap including the whole lateral nasal wall mucosa (360° flap, type D). The demographic and clinical data of the patients receiving extended nasoseptal flaps are summarized in Table 1.

There was satisfactory engraftment in all patients without any CSF leak on long-term follow-up. Intrathecal fluorescein was used in 2 cases for intraoperative CSF leakage detection and localization. A lumbar spinal drain was not used in any case. Olfactory function slightly decreased in 3 patients who received 360° flaps, but the patients did not complain of any discomfort in daily life because the olfactory function of the contralateral nostril was retained after surgery. One patient receiving a 360° flap experienced nasolacrimal duct obstruction because the mucosa was harvested too close to the opening of the nasolacrimal duct in the inferior meatus. This was treated by dacryocystorhinostomy. Crusting occurred and required daily nasal toilette that included self-administered saline lavages and moisturizing sprays and frequent debridement in the outpatient clinic. The patients came to the outpatient clinic for debridement every week for 1 month after the operation, and after that they came every 2 weeks for debridement until mucosalization was complete. Mucosalization of the donor site was observed within 8 to 12 weeks, and no anterior septal perforations were noted. No other infectious or wound complications such as partial or total loss of the flap were encountered.

Discussion

The introduction of vascularized endonasal flaps has significantly reduced the incidence of CSF rhinorrhea with the advantage of allowing rapid harvest.[8,12,15,16,32,33] Although the vascularized endonasal flaps can provide reliable, reproducible, and versatile reconstruction of the majority of skull base defects, each type of endonasal vascularized flap has limited applications because of its relatively limited surface area, arc of rotation, and reach.[3,6,14,18,29] Sometimes the limited surface area of a single conventional endonasal vascularized flap can be the cause of failure of a skull base reconstruction. If a very large skull base defect has resulted from a combined endonasal endoscopic approach to a large skull base tumor, or if a large invasive pituitary tumor leads to extensive skull base destruction, the skull base defect can be too wide for coverage or there may be multiple defects, and sometimes the location of the point of CSF leakage cannot be detected precisely. In these cases, the area on the skull base that needs to be covered may be beyond the potential dimensions of a single conventional endonasal vascularized flap. Although this clinical scenario is encountered rarely, it may be a life-threatening situation if the CSF leakage cannot be repaired.

Alternatively, various types of extranasal pedicled flaps can be applied for the reconstruction of large defects of the skull base, including a transfrontal pericranial flap,[43] a palatal flap,[28] a temporoparietal fascia flap,[11] an occipital galeopericranial flap,[35] and a facial artery buccinator flap.[34] These regional flaps can offer effective options for reconstruction in selected patients; however, they require a separate external approach that can be associated with donor-site morbidity, and, because of their technical difficulty, they are more labor intensive than endonasal flaps. The use of multiple endonasal vascularized flaps may be another viable option for extensive skull base defects. Since the first description of bilateral nasoseptal flaps by Hadad et al.,[15] one case series has demonstrated successful clinical experience with bilateral nasoseptal flaps for the reconstruction of large skull base defects that were not completely sealed by a single nasoseptal flap.[27] In another case series, an anteriorly pedicled inferior turbinate flap was used in conjunction with a contralateral nasoseptal flap because of the limited length of the nasoseptal flap, providing adequate sealing of a large skull base defect.[13]

TABLE 1. Clinical and demographic characteristics of patients using extended nasoseptal flaps (types C and D)

Case No.	Age (yrs), Sex	Pathology	Type	Prior Treatment	Site of Reconstruction	Preop CSF Leak	Leak Flow	Flap Type
1	48, M	Pituitary adenoma	PRL	Cabergoline	Sella/parasellar/tuberculum/clivus	Yes	High flow	NSF+ITF (type C)
2	53, M	Pituitary adenoma	PRL	Cabergoline	Sella/parasellar/planum/tuberculum/clivus	Yes	High flow	NSF+ITF (type C)
3	21, F	Pituitary adenoma	Nonfunctioning	TCA	Sella/parasellar/cribriform/planum/tuberculum/clivus/sphenoid wing/middle cranial fossa	Yes	High flow	360° flap (type D)
4	37, F	Pituitary adenoma	Nonfunctioning	Radiation	Sella/parasellar/planum/tuberculum/clivus	Yes	High flow	360° flap (type D)
5	51, F	Pituitary adenoma	Cushing	Pasireotide	Sella/parasellar/planum/tuberculum/clivus/sphenoid wing	Yes	High flow	360° flap (type D)

NSF+ITF = extended nasoseptal flap including the inferior turbinate mucosa; PRL = prolactinoma; TCA = transcranial approach; 360° flap = extended nasoseptal flap including the entire lateral nasal wall mucosa.

However, there are some drawbacks with the technique of using multiple vascularized flaps. Gaps between the flaps or overlapping of the flaps can cause inadequate skull base reconstruction, resulting in CSF leakage. In the case of invasive tumors with extensive skull base destruction, the border between the flaps, located in the middle of the destroyed area, can be the leak point after reconstruction, whereas a large single flap can cover the entire defect and be in direct contact with the surrounding margins. There is also the possibility of major septal perforation after raising bilateral nasoseptal flaps, which may be disadvantageous because sinonasal complications can occur and the contralateral nasoseptal flap cannot be preserved for future procedures.

To avoid these vulnerabilities and disadvantages of reconstruction using extranasal pedicled flaps or multiple endonasal vascularized flaps, modified vascularized nasoseptal flaps that are tailored or expanded to fit the size of a large skull base defect can be used. The extended nasoseptal flap including the nasal floor and inferior meatus mucosa (type B) has been described previously and demonstrated significant increases in reconstructive area and length in a cadaveric study.[2,3,15,30] Although this type of modification has the advantage of being easy to harvest, the extension of the reconstruction is limited to cover a defect from the tuberculum to the clivus.[30] To further expand the surface area and length, an extended nasoseptal flap including the inferior turbinate mucosa (type C) can be harvested for patients with extensive skull base destruction. In the cadaveric study, a posterior pedicled inferior turbinate–nasoseptal flap was demonstrated to be large enough to cover the ventral skull base from the posterior wall of the frontal sinus to the middle portion of the clivus.[41] We raised extended nasoseptal flaps including the inferior turbinate mucosa (type C) in 2 patients who had large invasive pituitary adenomas with extensive skull base destruction involving the sella, parasellar area, cavernous sinus, tuberculum, and clivus. The flaps showed robust, uniform enhancement on immediate postoperative T1-weighted contrast-enhanced MR images, and the CSF rhinorrhea completely resolved. In contrast to the inferior turbinate–nasoseptal flap based on the posterior lateral nasal artery described by Wu et al.,[41] we made a large flap based on the posterior nasoseptal artery, because this can provide a better arc of rotation to cover the skull base defect. For the 3 cases of invasive pituitary adenoma with extensive skull base destruction involving the frontal base, temporal base, sella, and clivus, we decided to raise an extended nasoseptal flap including the entire lateral nasal wall mucosa (type D, 360° flap). All 3 patients had massive preoperative CSF rhinorrhea, but their skull base defects were too wide to allow precise localization of the CSF leak (Figs. 2 and 3). We considered this a life-threatening condition that required complete sealing of the defect. We made the 360° flaps including the mucoperiosteum and mucoperichondrium of the nasal septum, nasal floor, inferior turbinate, nasal roof, superior turbinate, and middle turbinate, preserving its posterior pedicle, and covered the entire extensive skull base defect with the flap in direct contact with the margins of the defects. Fortunately, all flaps covered the entire defect and healed uneventfully with complete sealing of CSF leakage. Postoperative MR images showed robust, uniform enhancement of the flaps in all cases (Fig. 3E).

The 360° flap is the largest endonasal vascularized flap reported to date, and it has the potential to reconstruct an extensive skull base defect as a single large flap. In addition, despite the large surface of mucosa used, the size of the posterior septal defect after raising extended nasoseptal flaps was similar to that using a conventional nasoseptal flap. Because we elevated the septal mucosa unilaterally for the extended nasoseptal flap and performed a minimal posterior septectomy to make space for tumor removal, the contralateral septal mucosa and most of the bony and cartilaginous structures of the septum were retained. This contributed to the preservation of the normal anatomy of the septum while offering rapid healing and an additional option for subsequent skull base reconstruction using the contralateral nasoseptal flap. In the 5 patients in whom extended nasoseptal flaps were used, the donor sites in the nasal cavity became mucosalized within 2 to 3 months without serious complications (Fig. 4).

There are some limitations of extended nasoseptal flaps. One of the major limitations may be a possible shortage of blood supply. Although several anastomosing arteries between the posterior nasoseptal artery and the posterior lateral nasal wall artery were identified in the cadaveric

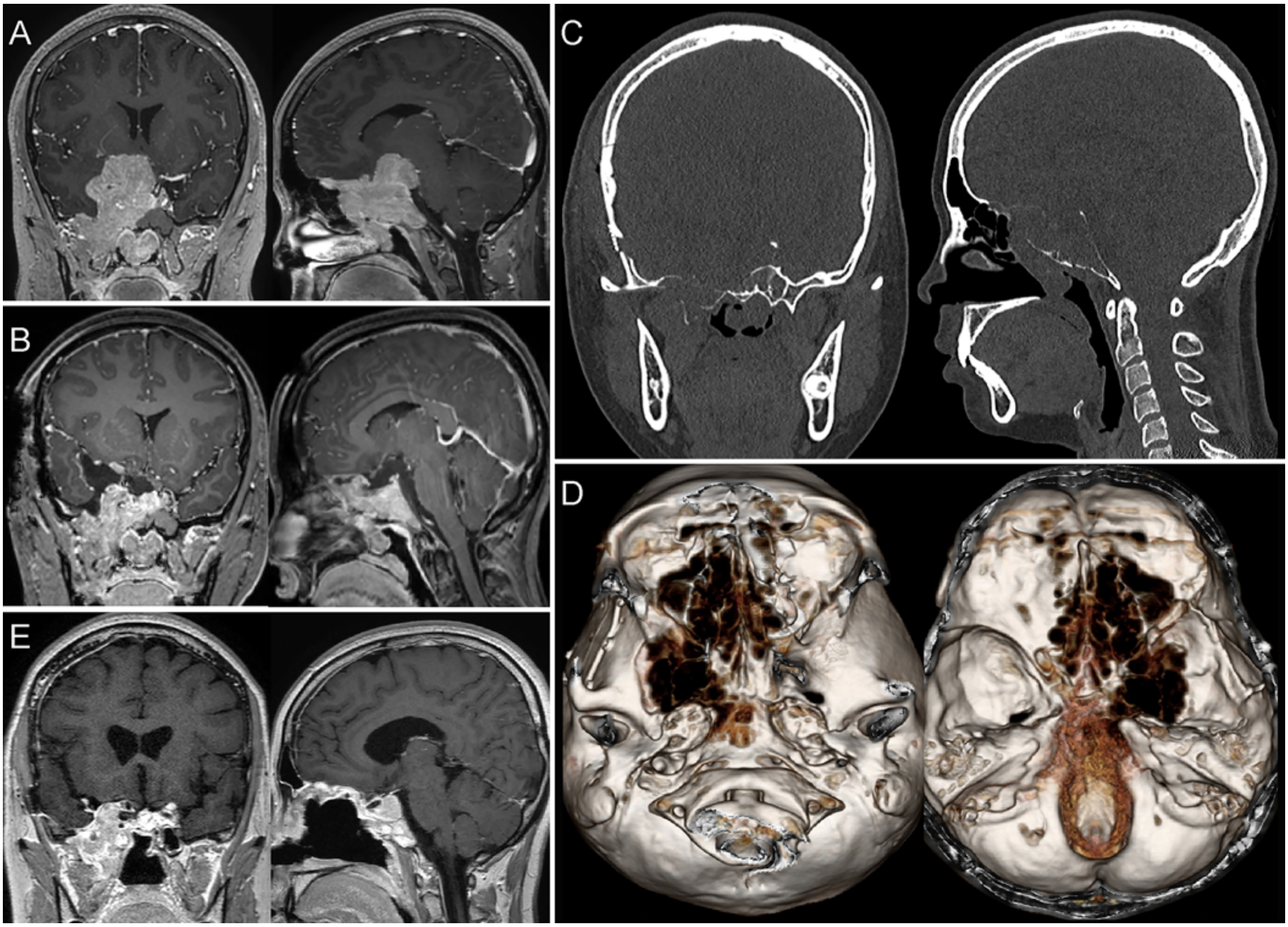

FIG. 2. Case 3. **A:** Coronal and sagittal T1-weighted contrast-enhanced MR images obtained before undertaking the transcranial approach. **B:** After partial removal of tumor via a transcranial approach was performed to decompress the optic nerve, CSF rhinorrhea developed. **C:** Coronal and sagittal CT scans demonstrating extensive skull base destruction by tumor invasion. **D:** 3D reconstruction images of CT scans showing a wide defect of skull base bony structure including sella, parasellar area, frontal base, left temporal base, left sphenoid wing, and clivus. **E:** Coronal and sagittal MR images obtained at 3 months, showing successful reconstruction with an extended nasoseptal flap including the whole lateral nasal wall mucosa (360° flap). Figure is available in color online only.

study,[41] it is unclear how well the nasoseptal artery supplies the mucosa of the lateral nasal wall. Accordingly, there is a possibility of necrosis of an extended nasoseptal flap including the inferior turbinate mucosa or the whole lateral nasal wall mucosa, because one vascular pedicle must supply a large surface area through the anastomosing arteries. However, in our series, all the extended nasoseptal flaps were well enhanced on postoperative MR images and healed completely without necrosis of the flap, demonstrating the likelihood of a prominent vascular network between the mucosa of the nasal septum and the lateral nasal wall. However, this is a new technique that was evaluated in a small group of patients, so the adequacy of the vascular supply should be validated in additional cadaveric and clinical studies.

Possible sinonasal complications may be another disadvantage of the extended nasoseptal flaps. Crusting can be increased compared with a conventional nasoseptal flap, because a much larger area of mucosa is elevated for the extended nasoseptal flap. Frequent debridement and self-irrigation of the nasal cavity until the abatement of crusting can reduce donor-site morbidity. We encountered a problem with lacrimal outflow in 1 case treated with elevation of the inferior turbinate flap, because the mucosal incision was too close to the opening of the nasolacrimal duct in the inferior meatus. This was a technical problem that can be avoided by curving the incision posterior to the edge of the nasolacrimal duct opening. Unilateral olfactory nerve injury is inevitable in the patients receiving a 360° flap, because the nasal roof mucosa of one nostril must be elevated, which may result in decreased olfactory function. However, the contralateral olfactory nerve is preserved so that the olfactory function can be retained, as was the case in the 3 patients in our series.

It can be technically difficult to harvest an extended nasoseptal flap because elevation of the middle and inferior turbinate mucosae is much more complex and technically challenging than the simple, straightforward technique

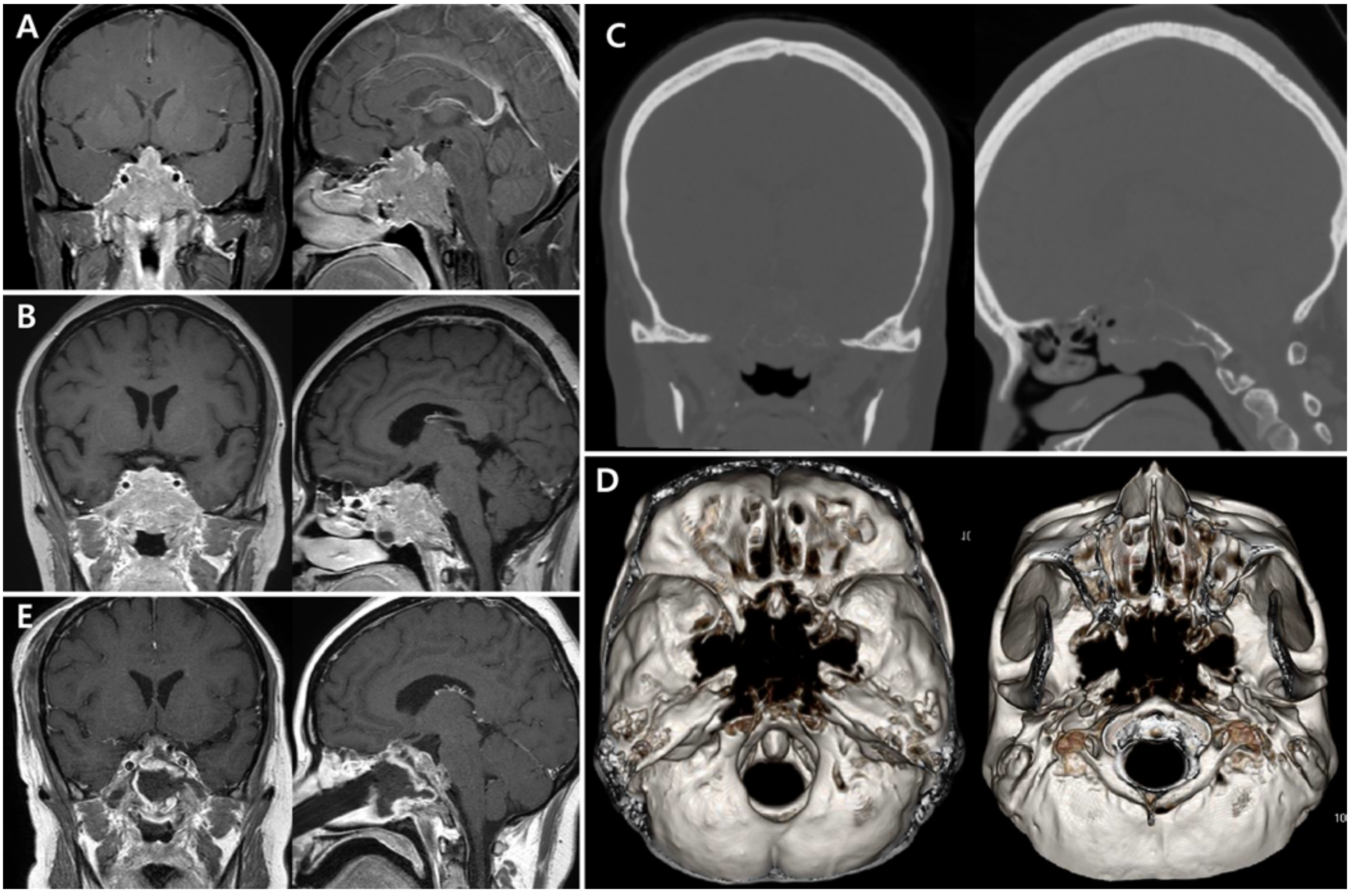

FIG. 3. Case 5. **A:** Coronal and sagittal T1-weighted contrast-enhanced MR images obtained before pasireotide medication. **B:** CSF rhinorrhea developed 1 month after initiation of pasireotide treatment because the tumor had shrunk. **C:** Coronal and sagittal CT scans demonstrating extensive skull base destruction by tumor invasion. **D:** 3D reconstruction image of CT scan showing wide defect of skull base bony structure including sella, parasellar area, planum, tuberculum, bilateral temporal base, bilateral sphenoid wing, and clivus. **E:** The extended nasoseptal flap including the entire lateral nasal wall mucosa (360° flap) covers the extensive skull base defect and shows robust, uniform enhancement on postoperative MR images. Figure is available in color online only.

required to elevate the nasoseptal mucosa. Anatomical variations make the procedure of the middle turbinate flap technically demanding, and elevation of the thin mucosa from the bone requires considerable skill.[3,32] The inferior turbinate flap is difficult to dissect from the bone of the turbinate because it adheres tightly.[8,12] The middle and inferior turbinate mucosae tend to retain their convex shape after elevation, so unfolding and positioning them to the dura defect requires considerable effort.[3] Handling a large single flap in the small nasal cavity can be another challenge to the adequate transposition of the flap. Nonetheless, the technical difficulty of making the extended nasoseptal flap can be overcome with the accumulation of surgical experience and training using cadavers.

Conclusions

In this study, we proposed the use of extended nasoseptal flaps as a good option for reconstruction of an extensive skull base defect. The 360° flap is the largest endonasal vascularized flap reported to date and can be a reliable option for the reconstruction of extensive skull base defects while avoiding an additional external approach. Ideal

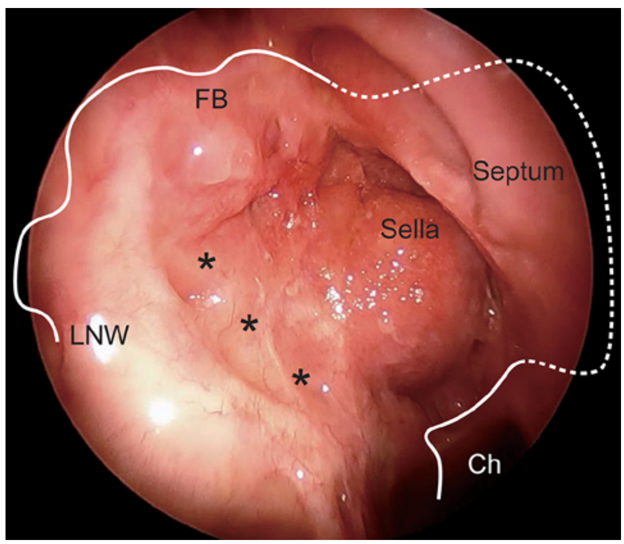

FIG. 4. Endoscopic photograph of the right nasal cavity obtained 2 years after the skull base reconstruction using extended nasoseptal flap (360° flap) in case 3. Note the space covered by extended nasoseptal flap (*dashed line*). The skull base dural defect on the right temporal area was completely sealed (*asterisks*). Ch = choana; FB = frontal base; LNW = lateral basal wall. Figure is available in color online only.

candidates for skull base reconstruction using an extended nasoseptal flap may be patients with extensive skull base defects resulting from destruction by large invasive tumors or complex endoscopic endonasal approaches. Further clinical experience using the extended nasoseptal flap is warranted to demonstrate its viability and reliability.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: SH Kim. Acquisition of data: Moon. Analysis and interpretation of data: Moon. Drafting the article: Moon. Critically revising the article: SH Kim, EH Kim. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: SH Kim. Statistical analysis: Moon. Administrative/technical/material support: SH Kim, EH Kim. Study supervision: SH Kim.

Supplemental Information

Videos

Video 1. https://vimeo.com/300765071.
Video 2. https://vimeo.com/300765086.

Previous Presentations

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